Flux dynamics in ultrasensitive superconducting focal planes

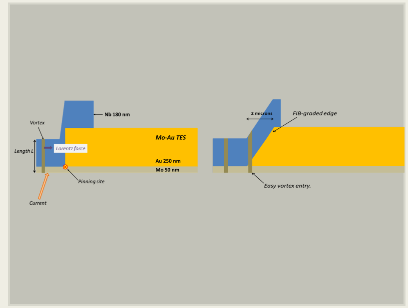
Completed Technology Project (2016 - 2017)

Project Introduction

The performance of superconducting focal planes will drive the achievable specifications of ultrasensitive instruments for NASA astrophysics missions, yet they have serious challenges with magnetic shielding in achieving their optimal performance. We will undertake a study to demonstrate suppression of flux dynamics that hinder detector performance for future NASA mission focal planes. We will further investigate capabilities relevant to NASA missions including lithographed or ion beam patterned designs for improving detector performance and field stitching for increasing array formats for future ultrasensitive imaging arrays.

GSFC has aggressive programs in superconducting focal planes including transition edge sensors (TES) for x-rays (ATHENA X-IFU) and infrared (HIRMES, PIPER), magnetic calorimeters, or MagCal, (X-ray surveyor) and kinetic inductance detectors (KIDs) for infrared spectroscopy and imaging (Microspec, Far-IR Surveyor). The TESs are susceptible to flux trapping and other effects of stray magnetic fields that cause degraded performance through “kinks” in the superconducting transition creating noisy bias spots. While a single detector can be shown to have good performance, large arrays will have degraded performance on average as some devices are forced to be biased on or near a kink.   While subtle, the effect can be measured in high fidelity testbeds uniquely available at GSFC. KID detectors consisting of superconducting microwave resonators experience a more direct degradation through reduction of the quality factor Q that defines the width of the resonance and correlates to the noise performance of the device.

1. We will identify length scales pertinent to flux trapping in superconducting leads – the so-called “Clem length” below which it is energetically unfavorable for the lead to contain magnetic field. We will show transition edge sensor performance in instrument relevant magnetic fields and confirm improved performance with sub-Clem length lead structures. [1]
2. We will demonstrate that other techniques for control of flux or “fluxonics” in superconducting structures can be beneficial to TES performance. [2] This effort will encompass the fabrication of graded interface structures for the elimination of vortex pinning. Focused ion beam will be employed as necessary for rapid prototyping and metrology at the nanoscale.
3. We will structure resonators lithographically to improve performance in the presence of magnetic fields for future KID designs including higher Q. [3]
4. We will further demonstrate enhanced capabilities critical for deployment of focal plane technologies (resonators, TES, and possibly others) including field stitching and ultrafine lithography. For these demonstrations, we will focus on mission enabling focal planes suitable for future proposals in both the x-ray and IR.



Grading the interface between superconducting circuit elements will vary the flux trapping environment near the sensor.

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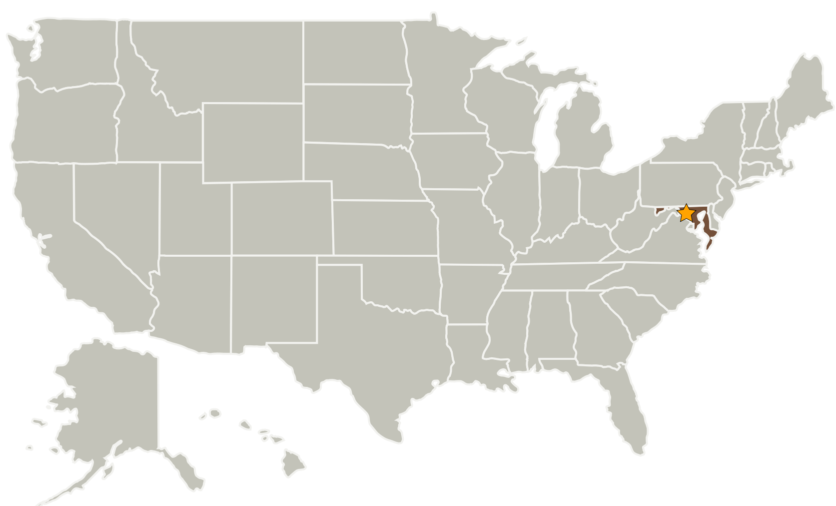
References:

1. JE Sadleir, “Superconducting Transition-Edge Sensor Physics”, Ph.D. dissertation at the University of Illinois Urbana-Champaign, 2010.
2. Silhanek, Van de Vondel, and Moshchalkov, “Guided Vortex Motion and Vortex Ratchets in Nanostructured Superconductors”, in Moshchalkov, Woerdenweber, and Lang (eds.), Nanoscience and Engineering in Superconductivity, Springer-Verlag, Berlin, 2010.
3. Song, DeFeo, Yu, and Plourde, “Reducing microwave loss in superconducting resonators due to trapped vortices”, *App. Phys. Lett.* **95**, 232501 (2009); doi: 10.1063/1.3271523

Anticipated Benefits

Large focal planes of ultrasensitive detectors for future missions will benefit from reduced magnetic sensitivity. Benefits to the FPA performance include increased uniformity. Benefits to the instrument design include lower mass dedicated to magnetic shielding and electromagnetic environment requirements.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Manager:

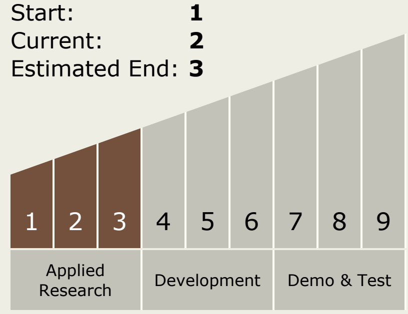
Terence A Doiron

Principal Investigator:

James A Chervenak

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **3**



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Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Maryland

Project Transitions

October 2016: Project Start

September 2017: Closed out

Closeout Summary: The purpose of the Goddard Space Flight Center's Internal Research and Development (IRAD) program is to support new technology development and to address scientific challenges. Each year, Principal Investigators (PIs) submit IRAD proposals and compete for funding for their development projects. Goddard's IRAD program supports eight Lines of Business: Astrophysics; Communications and Navigation; Cross-Cutting Technology and Capabilities; Earth Science; Heliophysics; Planetary Science; Science Small Satellites Technology; and Suborbital Platforms and Range Services.Task progress is evaluated twice a year at the Mid-term IRAD review and the end of the year. When the funding period has ended, the PIs compete again for IRAD funding or seek new sources of development and research funding or agree to external partnerships and collaborations. In some cases, when the development work has reached the appropriate Technology Readiness Level (TRL) level, the product is integrated into an actual NASA mission or used to support other government agencies. The technology may also be licensed out to the industry.The completion of a project does not necessarily indicate that the development work has stopped. The work could potentially continue in the future as a follow-on IRAD; or used in collaboration or partnership with Academia, Industry and other Government Agencies.If you are interested in partnering with NASA, see the TechPort Partnerships documentation available on the TechPort Help tab. http://techport.nasa.gov/help

Technology Areas

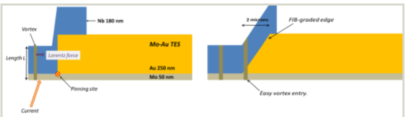
Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.1 Detectors and Focal Planes

Target Destinations

The Sun, Outside the Solar System, Foundational Knowledge

Images



Untitled Image 1
Grading the interface between superconducting circuit elements will vary the flux trapping environment near the sensor.
(https://techport.nasa.gov/image/26369)